I – Problem Statement Title (EQ 124)

The Effectiveness of Ground Improvement Techniques To Mitigate Liquefiable Soil

II – Research Problem Statement

Question: How effective are the ground improvement techniques to mitigate liquefiable soil?

Bridges and its components such as abutments, pile foundations, approach fills and embankments located at sites with shallow groundwater and/or adjacent to rivers and waterways are highly susceptible to earthquake-induced damage. Liquefaction of adjacent soils causes a significant amount of the damage to bridge abutments and embankments that is commonly manifested as ground failures, excessive lateral displacements, and/or settlements. There are many cases of widespread damage to bridge foundations and approach structures resulting from the lateral displacements and settlements of surrounding soil. In the past several decades the deep foundation industry has developed a variety of technologies that has been used as a solution to mitigate liquefiable soil, however, the effectiveness of these techniques for liquefaction mitigation has not been examined.

III – Objective

STAP Roadmap Outcome: 5- Improved Soil-Foundation-Structure-Interaction Analysis Tools, Techniques, and Methods (Problem #6: Develop technologies for ground improvement)

The objective of this study is to investigate typical ground improvement technologies for liquefaction mitigation and their effectiveness for bridges, embankments and deep foundations.

IV – Background

Following a major earthquake highways serve as the primary route of access. However, when the bridges (i.e., the main component of the transportation highway system) are damaged due to earthquake, the response and recovery will severely impede. Reviewing the reconnaissance reports from the past earthquakes demonstrate many occasions in which the bridge performed well from the structural viewpoint, however, excessive deformation of the bridge approach and adjacent foundation soils caused the bridge not to remain in operation after the earthquake. In addition, the magnitude and pattern of soil deformation around bridges often may result in damage to structural elements. So, the

serviceability of the bridges during earthquake is extremely important to public and highway Departments as well. Ground improvement is the solution to strengthen the soil around and below the bridges components.

Common ground improvement, ground treatment and ground reinforcement technologies are accomplished using many methods such as deep dynamic compaction, vibro-compaction, stone columns, deep soil mixing, micropile, EQ drain and other methods developed by the industry. Although the use of soil improvement methods is increasing, there are very few tools currently available for establishing the extent of ground treatment necessary to minimize earthquake damage.

V – Statement of Urgency, Benefits, and Expected Return on Investment

Foundations are the most expensive components of highway bridge construction. Typically the behavior of piled foundations is controlled by the soil properties in the upper layers of soil (approximately four pile diameters down from the bottom of the pile cap).Where foundation designs are controlled by lateral loading parameters and the number of piles increases as a result, soil improvement has shown significant positive benefits to the bridge construction.

VI – Related Research

The author of this problem statement has published extensively on subjects related to ground improvement, ground treatment and ground reinforcement. In addition, he was representing Caltrans in the 2002 AASHTO/FHWA International Technology Scan Tour to five European countries related to “Innovative technologies for accelerated construction of bridge and embankment foundations in Europe”, published by FHWA (2003).

Porbaha, A., Zen, K., and Kobayashi, M.(1999) Deep mixing technology for liquefaction mitigation, Journal of Infrastructure Systems, ASCE, Vol.5, No.1, 21-34.

VII - Deployment Potential

Recommendations on the effective methods, materials, and tools for mitigation of liquefiable soil. This study could be the first stage of a larger research project for further laboratory investigation, field monitoring, and evaluation of QA/QC issues in order to develop design and construction specifications for effective ground improvement technologies.